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KeyLED - Transmitting sensitive data over out-of-band channels in wireless sensor networks

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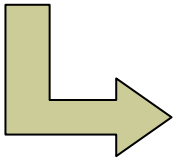
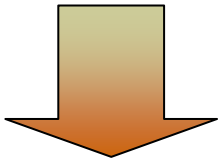
WSN Security
Out-of-Band Channels

- Sensor networks are specially vulnerable against external and internal attacks due to their peculiar characteristics
- Focus on attacks to the *Information Flow*
  - Easy access to the information of an (unprotected) wireless channel
- *"Out-of-band" Channels?*
  - Limited capabilities
  - Spatial relationship Sender ↔ Receiver
  - (Usually) require the presence of a human user



1. Devices are near when communication takes place
2. Difficult to Eavesdrop / Modify information flow
3. Human user can certify which is the sender & which is the receiver



Applicability?
Feasibility?

I. APPLICABILITY

Wireless Sensor Networks + “Out-of-Band” Channels

- Properties:
  - Two previously unrelated nodes can share sensitive information
  - Assume that the source device is physically near
- QUESTION: ¿IS THIS REALLY USEFUL?

WSN and “Out-of-Band” channels

- *Pre-Deployment Phase* – Configure the nodes
  - ✓ Load the motes with
    - Application-specific information
    - Node-specific sensitive information
  - – *When*? Configuring motes on potentially unsafe environments
- *Deployment Phase* – Establish pairwise keys
  - ✗ Not specially useful
    - Scalability
    - Practical reasons

WSN and “Out-of-Band” channels

- *Network Extensibility* – Add new nodes after deployment
  - ✓ Establish a pairwise key
    - Send ephemeral key to protect subsequent negotiations
    - Applicable to certain Zigbee configurations (“over-the-air”)
  - ✓ Send public information (e.g. Certificates)
    - “Nearness” – new node is physically near
- *Network maintenance* – Establish pairwise keys
  - ✓ Send parameters
    - “Nearness” and Privacy
      - Location privacy, Content privacy

Do not Forget: “Nearness” ≠ “Authentication”

(Still, adversaries need to be near their targets ☺)

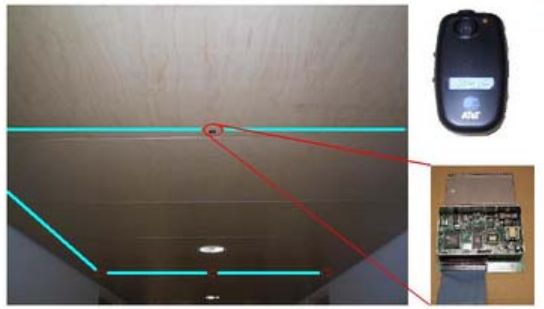
II. FEASIBILITY

Selecting an "Out-of-Band" Channel for Sensor Networks

- Analysis:
  - Different types of "Out-of-Band" channels
  - HW Requirements
- QUESTIONS:
  - ¿"OUT-OF-BAND" CHANNEL FOR SENSOR NODES?

“Out-of-Band” channels

- *Human users*
  - Read information from sender,
    → input information in receiver
  - Disadvantages:
    - HW Requirements (display, input)
    - Bandwidth is very constrained
  - Simplifications:
    - Single functional buttons
    - Acceleromenters – Shaking devices
- *Ultrasound*
  - Advantages
    - Signals stay inside a room (walls)
    - Derive (distance, position) of the sender



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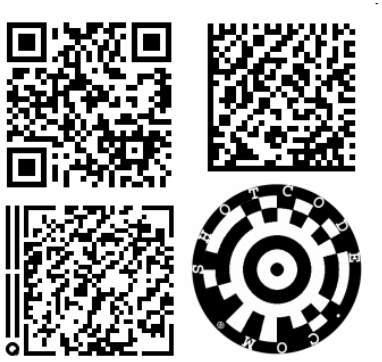
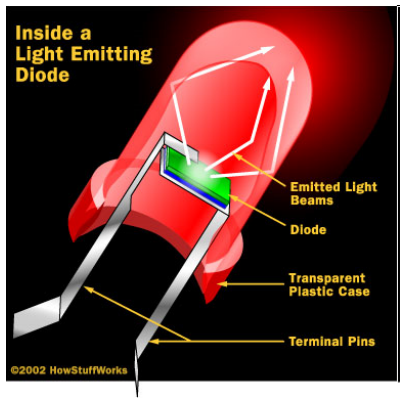
Bat System Image © 2002-2005 DTG, Computer Laboratory, University of Cambridge

“Out-of-Band” channels

- *Visual channel* – Camera
  - Image-based:
    - Data encoded as 2D barcode
    - Receiver (camera) takes a snapshot
  - Light-based:
    - Data encoded as pulses of light
    - Receiver (camera) detect changes
- *Optical channel* – Light
  - Unidirectional
    - Sender: LED
    - Receiver: Photosensor
  - Bidirectional
    - Sender + Receiver: BiDi. LED





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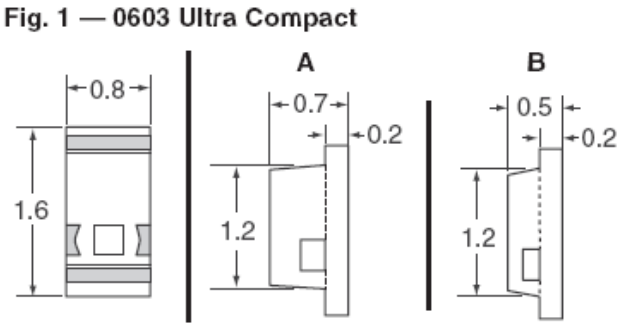
LED image © howstuffworks.com

“Out-of-Band” Channels
Feasibility

- Use *light* as a transmission channel (optical channel)
  - Most motes equipped with LED + Photosensor
    - And if not, they are cheap!
- Aspects to consider:
  - *Speed*? Limited by the speed of the LEDs / photosensors
  - *Transmission range*? Small (channel noise!)
  - *Activate channel*? Buttons / “Shake” / …



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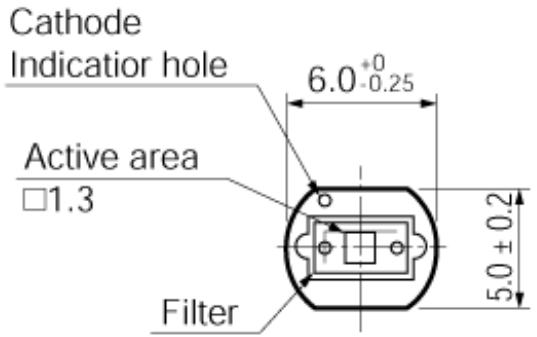

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III. SECURITY

Security of Optical Channels in Sensor Networks

- Optical channels are “weak”:
  - Easy to eavesdrop / inject messages
    - Light is cheap to produce and sense!
- QUESTION: ¿ARE THEY SECURE ENOUGH?

“Out-of-Band” Channels
Security Analysis

- Light is easy to capture and easy to produce
  - Attacks!
- ✗ *Man-in-the-Middle Attack*
  - Improbable – User Interaction
- ✗ *“Nearness” and Packet Injection*
  - Long-distance communication channels through laser diodes
    - Need to have a lens in the receiver side
  - Use other short-range communication technologies
    - Need unobstructed view between receiver and rogue sender
    - Photosensors that do not sense Infrared light (IrDA)
      - The user can “see” the attack

“Out-of-Band” Channels
Security Analysis

- ✘ *Denial of Service attack (DoS)*
  - Modify the ambient light
    - The user can “see” the attack, adaptative sensing
  - “Blind” the photosensor of the receiver
    - The user can “see” the attack + Need of an unobstructed view
- 😐 *Eavesdropping*
  - Humans cannot “see” if the channel has enough speed
  - …but machines can! (Professional digital camcorder: 1000 fps)
  - …and also specialized equipment can sense it (read info <30 meters)
    - Limit the optical emanations (closed room, covering nodes)
    - Use more than one color to transmit information (optical pass filters)

IV. IMPLEMENTATION

Implementing an Optical Channel in a Mote

- What we need to prove?
  - Feasibility, Speed, Usability
- QUESTION: ¿CAN WE IMPLEMENT A FEASIBLE, FAST, USABLE OPTICAL CHANNEL?

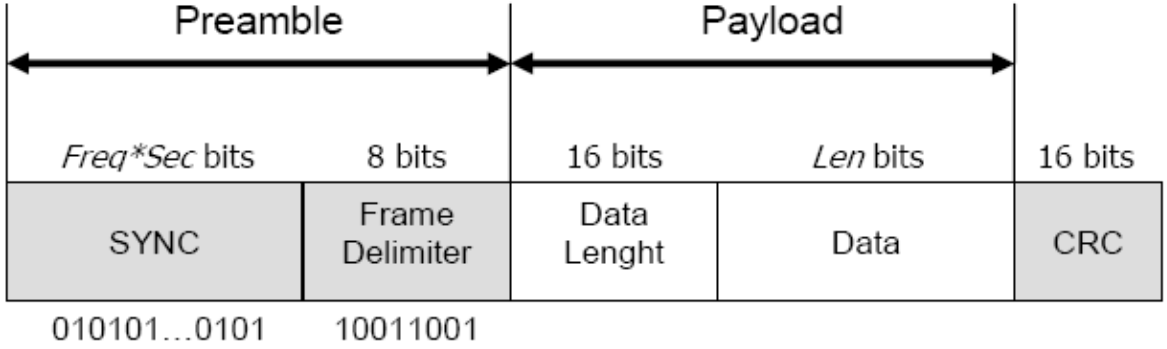
Implementation
Design decisions

1

Blue LED (0.05 lumens)

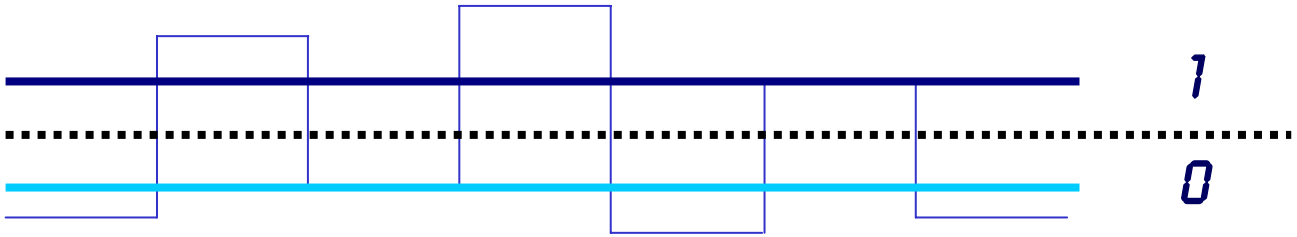
(3000 lx. on contact)

2



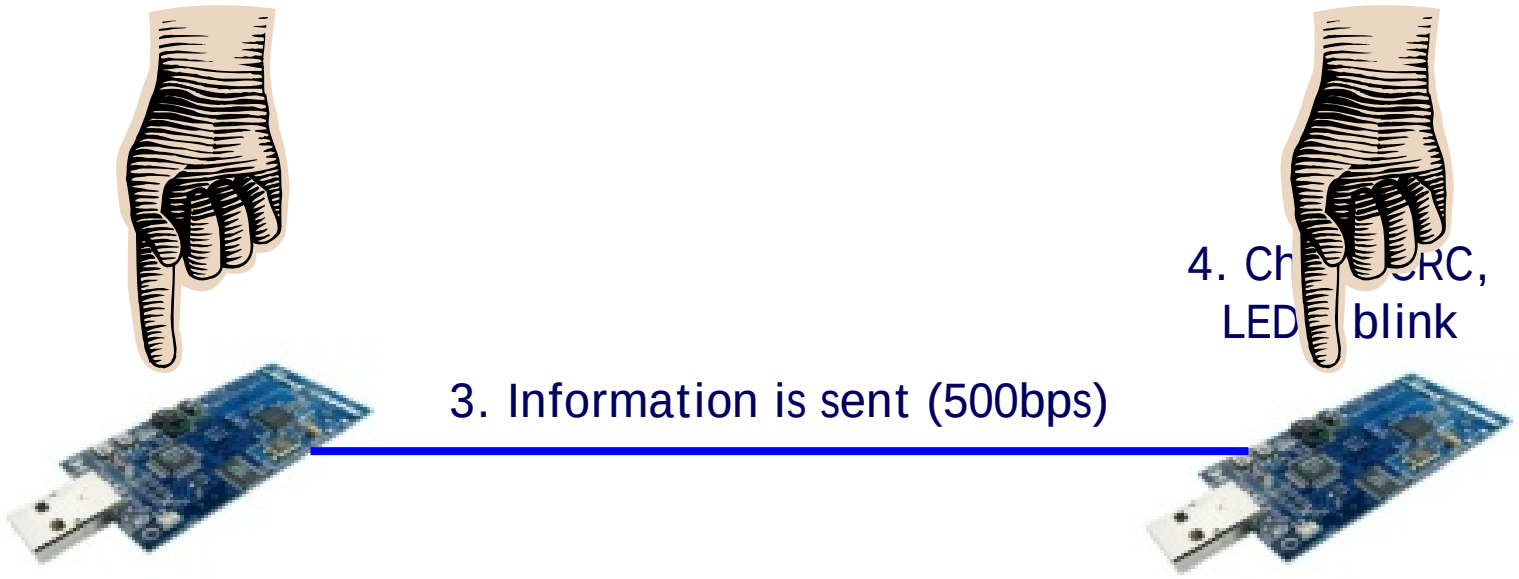
- OOK (On-Off Keying), Raw bitrate predefined at design time

3



- Dynamically define a threshold during the SYNC block → Adaptative

Implementation
Experiment



Implementation
Experiment

- *Speed*: 500bps
  - AES-128 key: 0.256 sec.
  - ECC Public key: 0.704 sec.
- *Usability*: 12 tests subjects
  - Arithmetic mean of n# attempts: 2.166
  - Std. Deviation: 0.799
- *Feasibility*
  - Sender: 54B RAM, 1kB ROM
  - Receiver: 126B RAM, 5kB ROM
  - Illuminance conditions: Small transmission range, almost all scenarios

Ambient light conditions	Light Intensity	Max. Trans. range	Number of trials
Clear night	4 lx	6 cm	5 / 5
Incandescent light	100 lx	3 cm	5 / 5
Fluorescent light	70-140 lx	3 cm	5 / 5
Cloudy day	2700 lx	Contact	5 / 5
Sunlight	3400 lx	Contact	0 / 5

V. CONCLUSIONS

An optical channel for sensor networks

Conclusions

- What are the questions we have answered?
  - "Out-of-band" channels **are useful** for sensor networks
    - Pre-deployment phase, Network extensibility, Network maintenance
  - **Cheap** "Out-of-band" channel for motes
    - Optical channel using LEDs and Photosensors
  - Optical channels do provide the necessary **security properties**
    - Need to take into account the eavesdropping issue
  - The optical channel is **feasible, reasonably fast, usable**
- What are the questions we have raised?
  - Are the benefits good enough to consider its application outside research environments
  - Is it possible to receive information from *any* light emitting device?
    - Interoperation in Pervasive environments


¡GRACIAS!
Time for
Questions ☺